

United States Patent

3,614,760

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100-120

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(21) GRANULATING APPARATUS

11 Claims, 13 Drawing Figs.

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40 is resonating, full wave rectified DC power is made available across the other corners 204 and 206 of the bridge 201. A portion of the resulting ripple voltage is short circuited by a filtering capacitor 208 connected across the DC output terminals. The negative output terminal 206 is grounded, and the positive output terminal 204 of the rectifier circuit provides B+ voltage to a pair of Colpitts oscillator circuits 208 and 210.

(12) The B+ voltage is applied through respective limiting resistors 212 and 214 to respective inductors 216 and 218 which, together with respective capacitors 220 and 222, form the oscillator tank circuits. The other end of each tank circuit is connected to the collector of respective transistors 224 and 226. The return path for the DC power proceeds from the emitter electrode of each transistor through respective radiofrequency chokes 228 and 230 and emitter load resistors 232 and 234 to ground. Respective capacitors 236 and 238 provide additional ripple filtering.

(13) The circuits 208 and 210 are emitter follower transistor Colpitts oscillators having the usual capacitive voltage dividers 240, 242 and 244, 246 respectively connected across the tank circuits to establish a desired level of feedback. The base connections of transistors 224 and 226 are provided by limiting resistors 248 and 250, shunted by respective capacitors 252 and 254 to provide low-impedance radiofrequency feedback paths. Each of the oscillators 208 and 210 is tuned to its own respective radio carrier frequency, designated f1 and f2 in FIG. 6. Respective antennas 256 and 258 are provided for radiating at carrier frequencies f1 and f2. Thus, oscillator 208 and its antenna 256 comprise a first radiofrequency transmitter 257 broadcasting at frequency f1, while oscillator 210 and its antenna 258 comprise a second radiofrequency transmitter 259 broadcasting at frequency f2. Both transmitters broadcast only during the short interval when resonant vibration of the spring-mass system 38, 40 of generator 20 provides the necessary power for energizing the oscillator circuits.

(14) But the generator voltage is not only used as a power supply for the oscillators 208 and 210. It is also applied over leads 260 and 262, limiting resistors 264 and 266, and chokes 228 and 230 respectively to modulate the outputs of the transmitters 257 and 259. The alternating output potential of the generator 20, at the frequency of mechanical vibration of the spring-mass system 38, 40, develops an alternating modulation signal across the respective

United States Patent

Wilson

3,683,351

3,683,351

[44] PRIORITY DETECTOR

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[11] Appl. No. 1,351

[37] U.S. CL. 340/128 C, 340/128 A
Int. Cl. F24F 1/00

[50] Field of Search: 340/128 C, 340/128 A

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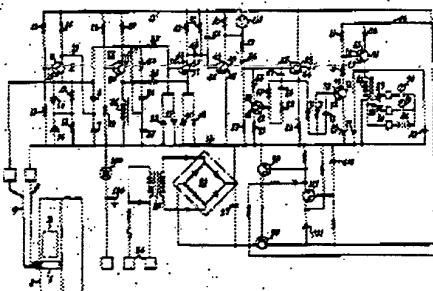
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Assistant Examiner: Michael Schaefer
Attorney: George H. Baldwin and Arthur G. Yeager

[57] ABSTRACT

An electronic system for detecting the presence of an external object in the field of view of the receiver in the tank circuit of the detector is a pair of oscillators. The oscillators are interconnected for frequency

synthesizers. The tank circuits of the oscillators are tuned to have different natural resonant frequencies in the absence of an object whereby the oscillator signal output is phase. The presence of an object affects the natural resonant frequency of the tank circuit and the tank circuit is in resonance or series to decrease the natural frequency of the tank circuit caused by the object. The antenna output signals are locked, fed to a phase detector, and a signal is developed representing the phase difference. When signal frequencies have a predetermined threshold, an output signal is developed to provide an indication of the presence of the external object. The threshold is established in part by a capacitor having a charge representing ambient conditions when no object is present. The charging circuit for the capacitor provides a slow rate of change to allow gradually increasing the threshold as the object approaches. The signal developed in the phase detector is then used to generate change in the charge on the capacitor as the result of the relatively more rapid and large change in the impedance of the resonator element as the external object moves within the detection field. The logic peak detector circuit is operative to provide an output signal to the charge control circuit after a time delay following the detection of an arriving object to cause the object has cut in the beam dispersed from the field. The departure of the object from the field prior to the time that the charge has been from the ordinary expansion, prevents the output change from occurring. The system is particularly adapted to indicate presence of vehicles within the field of a loop disposed slightly below the surface of a roadway or driveway.

6 Claims, 3 Drawing Figures



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elements 6 and 7 which are connected in series. Elements 6 and 7 in the circuit shown comprise capacitors constituting with inductance loop 1 a frequency determining circuit of an oscillator generally identified by the numeral 8. The circuit of inductance loop 1 and capacitors 6 and 7 comprises a tank circuit. The oscillator includes a PNP-transistor 9 having its emitter connected through resistor 10, which may be 470 ohms, to positive bus 11, and with its base connected to the juncture of voltage divider resistors 12 and 13 which are connected in series from positive bus 11 to negative bus 14. Resistor 12 connected between the base and the positive bus may be of 10K ohms while resistor 13 connected from the base to the negative bus may have a resistance of 3.3K ohms. One of the leads 4 from the loop 1 is connected to collector 15 of transistor 9 while the other lead 5 is connected to the negative bus. A network comprising Zener diodes 16 and 30, each of which may be of type 1N757, and resistors 17 and 18, each of 0.1 megohm, is connected between the negative bus and the collector of transistor 9. The cathodes of the diodes are interconnected and connected to the juncture of the serially connected resistors 17 and 18, while one resistor is connected at its free end to the collector 15 and the other resistor 18 is connected at its free end to the negative bus. The anode of one diode is connected to the collector 15 and the anode of the other to the negative bus.

(2) Oscillator 8 is arranged as a Colpitts oscillator, with the emitter of transistor 9 connected by a lead 19 to the midpoint or juncture of capacitors 6 and 7, each of which may be 0.1 mfd.

(3) A second Colpitts oscillator is identified at 20 and comprises a transistor 21 which, like transistor 9, may be of type 2N3906. The base of transistor 20 is connected to the juncture of resistors 22 and 23 which are connected in series from the positive to the negative bus. These resistors correspond respectively to resistors 12 and 13 of oscillator 8 and may be of the same respective resistance values. The circuit for collector 24 of transistor 21 comprises a variable inductance 25 connected between the collector and the negative bus and connected in parallel with series connected capacitors 26 and 32 to form a tank circuit. Capacitors 26 and 32, like capacitors 6 and 7, may be of 0.1 mfd., and the mid-point between these capacitors is connected by lead 27 to the emitter of transistor 21. The emitter is further connected through a 1,000 ohm resistor 28 to the positive bus. The oscillators are coupled by a coupling impedance in the form of a common lead resistor 29 which may be of 470 ohms and which is connected

(19) Starting with the tank circuits tuned to the same natural resonant frequency, the inductance of coil 25 is next adjusted to increase the natural resonant frequency of the tank circuit of internal oscillator 20 to provide a predetermined voltage across resistor 50, which may be read on voltmeter 110. In a typical system properly tuned and adjusted, this voltage will be 10 volts. Since the oscillators 8 and 20 drive each other into synchronization through the common load or coupling resistor 29, the result of such tuning of the tank circuit of oscillator 20 is to cause the output signal therefrom as applied to the emitter of transistor 35 to be advanced in phase with respect to the phase of the voltage from the loop oscillator, as applied to base 34. During the period that the base 34 is positive, curve 144, with respect to the emitter, as represented by curve 146 in the section of FIG. 2 titled "Tuned for Operation," that is, for the time T1, the output voltage at collector 42 becomes less positive. These recurring less positive pips establish a potential across storage capacitor 54 representing the ambient condition.

(20) As heretofore pointed out, the tank circuit of the internal oscillator 20 is adjusted to have a resonant frequency higher than the frequency of the loop oscillator 8 in the absence of an external object over the loop. An external object in the presence of the loop tends to reduce the inductance thereof and thereby increase the resonant frequency of the tank circuit of the loop oscillator. The oscillators are so inter-connected that they drive each other to be and remain locked in synchronization as to frequency but the phase of the loop oscillator signal lags that of the internal oscillator. Accordingly, the base of transistor 35 is positive with respect to its emitter for time T1 as shown in FIG. 2. With the device properly tuned in the absence of an object over the loop the integrated voltage across resistor 50 is typically 10 volts.

(21) The signals corresponding to the presence of an automobile are shown in the curves over the legend "Vehicle Detected" in FIG. 2. The loop oscillator signal 154 has decreased in phase difference with respect to the internal oscillator signal 156 and now the base of transistor 35 is positive with respect to the emitter for the shorter time T2, and the integrated voltage produced across resistor 50 is lower, and typically approximately 7 volts, whereby a reverse bias is applied is applied to the base of transistor 56 through capacitor 54, cuts off transistor 56, thereby reducing the potential on collector 61. ~~which in turn results in a reduction in the voltage at the base of transistor 35~~

potential on the base of transistor 56. Transistors 60 and 56, accordingly, regeneratively become fully conductive, and the increased potential of the collector of transistor 56 causes transistors 74 and 75 to become conductive. It will be apparent that the length of time after the vehicle has arrived over the loop, and after the voltage across resistor 50 has been reduced, during which transistor 56 remains reverse biased is dependent upon the value of resistor 57 and, of course, upon the value of the memory capacitor 54. At any time that the external object removes from the location of the loop 1, the tuning of the tank circuit of oscillator 8 is affected to reestablish the conditions represented by the "Tuned for Operation" curves, with the voltage across resistor 50 re-established at 10 volts. The signal applied to capacitor 54 upon leaving of a vehicle is in the direction to tend to increase conductivity of transistors 56 and 60, whereby the charge on capacitor 54 is quickly re-established in accord with the ambient inductance of loop 1.

(22) Gradual changes which may occur in the inductance of loop 1, as a result of changing temperatures or the occurrence of rain, do not occur with sufficient rapidity to cut off transistors 56 and 60, whereby the charge on capacitor 54 continuously adjusts to the ambient conditions through the short time constant circuit through resistors 58 and 61 and the collector-emitter circuit of transistor 60.

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Kellman

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(43) Nov. 22, 1977

(54) PAUL-DEJET TIME DELAY CIRCUIT

(71) Inventor: Dale J. Kellman, Glenside, Pa.

(73) Assignee: Whetstone Air Brake Company, Philadelphia, Pa.

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U.S. Cl. 340/136, 136.1, 136.2; 136.3; 136.4

(31) Field of Search: 177/141.3, 141.2, 141.1

313/143.2; 340/136, 136.1, 136.2, 136.3

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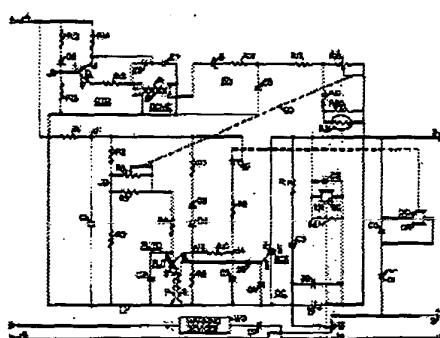
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Assistant Agents or Filed—J. D. Scott; S. W. Michtchuk
St.

(57) ABSTRACT

A failure time delay circuit comprising a detection relay for monitoring the pressure and state of a liquid system, a normally closed contact for connecting a first and second contacts in conjunction with the presence and absence of the liquid signal, and a programmable junction controller, including circuit, a timer connected to the normally open contact and a normally closing circuit including a normally closed contact, the normally closing circuit being connected by the normally open contact of the switching relay for providing a predetermined time delay period between the disappearance and the represence of the liquid signal prior to activating the normally closed relay connected to the circuit.

13 Claims, 8 Drawing Figures

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includes a PNP transistor Q having an emitter electrode e, a base electrode b and a collector electrode c. The base electrode b is connected to the junction point J5 of a voltage divider including resistor R12, diode D6 and resistor R13. The upper end of resistor R12 is connected to positive voltage terminal 4 while the lower end of resistor R13 is connected to common lead L1. The emitter electrode e is connected to the positive supply terminal 4 via swamping resistor R14. The collector electrode c is connected by resistor R15 to a tank circuit formed by primary winding P1 of transformer T1 and capacitors C6 and C7 which constitute the frequency determining components of the oscillator. The capacitors C6 and C7 form a voltage divider network, and the junction point between the capacitors is connected to the emitter electrode e of transistor Q. The remote ends of capacitor C7 and primary winding P1 are directly connected to the common lead L1. The a. c. oscillations developed in primary winding P1 are induced into the secondary winding S1 of transformer T1. The a. c. oscillations developed in secondary winding S1 are fed to the half-wave rectifier network RN. As shown, one end of the secondary winding S1 is directly connected to common lead L1 while the other end of secondary winding S1 is connected to the anode electrode of Zener diode Z. The cathode electrode of Zener diode Z is connected to one end of current limiting resistor R16 while the other end of resistor R16 is connected to the upper plate of filtering capacitor C8. The lower plate of the capacitor is connected to common lead L1. The other end of resistor R16 and the upper plate of capacitor C8 are connected to series-parallel connected resistors R17 and R18, variable resistor or potentiometer R19, resistor R20 and thermistor R21. As shown by phantom line 20, the potentiometer R19 is mechanically coupled or ganged together with potentiometer R6 so that proportional variation in resistances occur when an adjustment is made. The resistors R17, R18, R19, R20 and thermistor R21 are connected to the charging capacitor C and form an R-C timing circuit having a time constant which is related to the time constant of R4, R5, R6, C2 timing circuit due to the ganged connection of resistors R6 and R18.

(9) For the purpose of convenience, warning devices WD and a blocking diode D7 are shown connected between B+ terminal and B- terminal of a common or separate source of D. C. supply voltage over the back contact by the movable contact bs. Thus, the warning devices, such as, the flashing lights, bells, horns, whistles, gates or the like, are activated over the back contact of relay SR by movable contact bs.

its back contact to be opened by picking up movable contact ad.

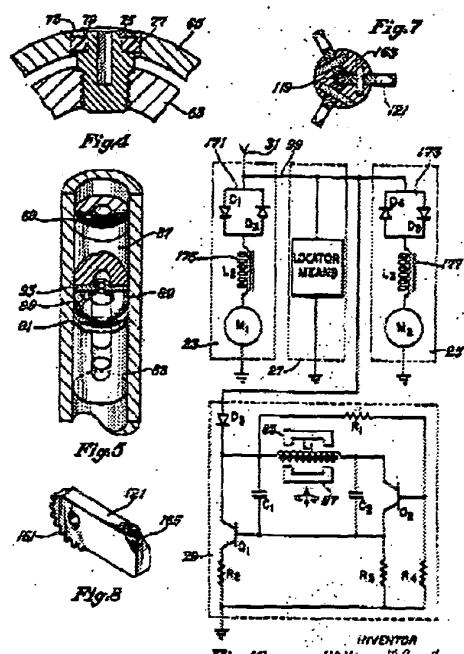
(11) When the back contact is opened by the disengagement of movable contact ad, the potential level at junction point J3 will assume a value which will result in the conduction of the transistor PUT when the voltage on the anode electrode a reaches a predetermined level, namely, when the voltage difference between the anode and gate junction of transistor PUT is by one diode forward voltage drop. That is, the voltage level on gate electrode g is determined by the ratio of R8 which is designed to be lower than the voltage appearing at junction J2. It will be appreciated that when the capacitor C2 begins to charge, the Colpitts oscillator CTO of the d. c. making circuit DCMC also starts to produce a. c. oscillation which are transformer coupled to the rectifier RN. The d. c. voltage produced by rectifier network RN begins charging the capacitor C through the series-parallel connected resistors R17, R18, R19, R20 and thermistor R21. It will be appreciated that the charging rates of capacitors C2 and C are interrelated due to the gang connection of the respective resistors R6 and R18. Now when the charge on capacitor C2 causes the voltage on anode electrode a to exceed the voltage on gate electrode g, the transistor PUT conducts and causes a voltage pulse to be developed in primary winding P which, in turn, induces a trigger pulse into secondary winding S. The trigger pulse is conveyed through diode D5 to the gate electrode g of silicon controlled rectifier SCR which causes it to fire. The conduction of the SCR establishes a discharge circuit path for capacitor C through resistor RSR and inductive coil SC, through the anode-cathode electrodes a - k, back to the capacitor C so that relay SR is picked-up thereby opening its back contact and closing its front contact over movable contact as. With the front contact closed, the relay SR will remain energized over its stick circuit by the input signal appearing across terminals 2 and 3. The opening of the back contact by movable contact ad removes the negative operating potential from the oscillating circuit PUTO and the d. c. making circuit DCMC so that they are rendered inoperative. This condition will prevail so long as no approaching train or vehicle enters the detection track section and no other event, such as, a broken lead, an open bond wire, or the like, causes the loss of the input signal on terminals 2 and 3.

(12) Now when a train or vehicle enters the detection track section, the signal voltage normally appearing across input terminals 2 and 3 are shunted by the front wheel and axle. The absence of the input signal on terminals 2 and

Patented Aug. 29, 1972

3,686,943

3 Claims-Cont'd 5



polarity such as positive voltage. The diode D3 is serially connected with ground via the collector and emitter of transistor Q1 and the current limiting resistor R2. Transistor Q1 serves as an amplifier to amplify the oscillations from a standard type oscillator such as a Colpitts oscillator. As is well known, the Colpitts oscillator employs a "tank" circuit, comprising capacitors C1 and C2 that are serially connected via inductance coil L1. The transistor Q2 serves as the oscillator transistor to keep the tank circuit oscillating. The resistors R1, R3 and R4 effect the appropriate biasing. The frequency with which the oscillator oscillates depends upon the magnetic field sensed by the inductance coil L1 intermediate permanent magnet 83 and the movable magnet 87. The inductance coil L1 comprises the sensing coil 89. The poles of the magnets as well as the distance of separation affects the magnetic flux sensed by the inductance coil L1. As the movable magnet 87 is moved, the magnetic flux changes about inductance coil L1 and intermediate the fixed magnet 83 and movable magnet 87. Consequently, the frequency with which the tank circuit oscillates is changed. The half wave of the oscillator signal passing diode D3 is transmitted via conductor 99 to the surface equipment 17. The change in the frequency of oscillation is then amplified and detected, as described hereinbefore, via amplifier 53, converter 55 and DC volt meter 49. The oscillator, including its tank circuit comprising capacitors C1 and C2 connected via inductance coil L1 and employing the oscillating transistor Q2, is well known in the art; does not, per se, comprise the invention; and requires no further description herein. It and satisfactory other oscillators are described adequately in standard texts.

(25) In operation, the borehole tool 21, suspended via cable means 19 and connected via its associated conductors, as described hereinbefore, is lowered into the borehole to a predetermined depth. The depth is ordinarily the point at which it is desired to know whether or not a conduit such as conduit 11 is stuck in the borehole. At this point, the reversing switch 45 is moved to the set position, indicated by S, and the rheostat 47 turned to a predetermined scalar magnitude. The predetermined scalar magnitude may be a value equal to about 75 percent to 90 percent of a predetermined setting value. The operator observes the ammeter 41. The ammeter will go to a high value to indicate that the motors in the one or more attachment means in the upper and lower portions 23 and 25 are starting; then will subside to a relatively low value as they run to outwardly extend the attachment members, or feet 121, to engage the conduit 11. As the motors run to stall, the current indicated by ammeter 41 will go to

Details

Text

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Lx is changed in the LC resonance circuit.

(5) The Colpitts oscillator to the left of phantom line 20, together with the feedback circuit to the right of phantom line 20, forms a variable frequency oscillator (or frequency modulated oscillator) which is current controlled by the base current applied to Q2, which in turn is determined by Vm. The output voltage of the circuit, namely Vo, is a combination of the oscillator frequency or carrier frequency (Fc) determined by the LC resonance circuit, plus harmonics of Fc, plus the modulation frequency of Vm. Put differently, the frequency Fc at Vo is a frequency modulated carrier with a base band modulation of Vm frequencies.

(6) It is possible to employ the circuit shown in FIG. 1 to demodulate a frequency modulated signal. Specifically, if a carrier current Fc of a frequency modulated signal is injected into the circuit at the emitter of Q1, such as at node N1 then the oscillator Q1 will lock to the frequency of the carrier. This locking of the oscillator causes the frequency of the carrier to appear at output Vo as well as all frequencies of the base band modulation of the frequency modulated carrier applied at node N1. By first passing the output voltage through a low pass filter circuit F1 a demodulated signal will appear at Vo.

(7) The circuit shown in FIG. 1 has many of the characteristics of the circuit shown in the '195 patent. A major improvement of this circuit over the previous circuit is the counteraction of the Miller effect capacitance, or Cb'c, which limits the high frequency operation of the circuit. The present circuit has been satisfactorily operated, both as a modulator and as a demodulator, at gigahertz frequencies.

(8) The circuit shown in FIG. 1 incorporates certain inherent compromises. For example, it effectively applies modulation to the phase lock loop incorporating the LC resonance circuit, which tends to spoil the impedance of this loop. This and other compromises of the FIG. 1 circuit are effectively eliminated in the circuit schematically illustrated in FIG. 2. In this circuit, the components whose operation and effect is substantially the same as those shown in the FIG. 1 circuit are identified by similar reference letters and numbers.

the semiconductor selected as Q2", the value of C7" very likely will change.

(20) Among the difficulties presented by the FIG. 3 circuit are some related to the nature of the LC tank circuit formed by L1", C1" and C2". This is not a true .pi. circuit. The circuit could have been designed such that it was a true .pi. circuit, with the common connection between the capacitance being grounded, but that would present a biasing problem. Another problem with this circuit is the difficulty it presents in attempting to shift the center frequency F_C with the diode D1". This may well have been related to the fact that the tank circuit was not a true .pi. circuit. Various ways to resolve this problem will be apparent to those of ordinary skill in this field, including, for example, dividing L1" and providing a choke.

(21) Another circuit that uses high frequency semiconductors of the same polarity as Q1 and Q2, and which exhibits significant advantages, is shown in FIG. 4. In it capacitor C6* is effectively hooked between the base and collector of Q2* to neutralize its Miller effect capacitance. The tank circuit L1*, C1* and C2* is connected between the base of Q2* and the collector of Q1*. Feedback from Q2* is provided through resistor R3* to the emitter of Q1*. The control voltage through VCO* is supplied to Q1* through C7*. The RF output of the circuit is also taken from the collector of Q1*, resistor R14* decoupling the output from the circuit. The semiconductor Q3* compensates for the base to emitter diode effect of Q2* over a temperature range, controlling the current in Q2* and thereby stabilizing the circuit.

(22) The operation of the FIG. 4 circuit is similar in significant respects to the operation of the previous circuits. To understand what appears to be the case, it is necessary to consider the phases of the currents and voltages in the LC tank circuit. The voltages through the inductor L1* and through the capacitor C1* and C2* all appear to be in phase. However, the currents in the tank circuit elements are in quadrature. The voltage in C2* lags the current in C2* which results in the current at the collector of Q2* being in quadrature with the current at its base. This is fed back to L1* through C6* and reinforces the current through L1*. The effect in the FIG. 4 circuit appears to be that the phantom inductance, L_x , is in parallel with inductor L1*, rather than being in series with it. This means that it tends to increase the frequency of the tank circuit. If both Q1* and Q2* are gallium arsenide NPN semiconductive elements, it is possible to obtain such components currently

means to the emitter of the first amplifier means, the capacitor means being attached between the base and collector of the second amplifier.

4. A high frequency oscillator circuit as set forth in claim 3 in which the first amplifier and first means form a Colpitts oscillator circuit.

5. A high frequency oscillator circuit as set forth in claim 1 including fifth means to stabilize the biasing potential applied to the first amplifier.

6. A high frequency oscillator circuit as set forth in claim 5 in which the fifth means includes a third amplifier means.

7. A high frequency oscillator circuit as set forth in claim 6 in which the third amplifier means is connected between the base and emitter of the second amplifier.

8. A high frequency oscillator circuit as set forth in claim 1 including sixth means to stabilize the bias applied to the second amplifier.

9. A high frequency oscillator circuit as set forth in claim 8 in which the sixth means includes a fourth amplifier means.

10. A high frequency oscillator circuit as set forth in claim 9 in which the fourth amplifier means is connected between the base and the emitter of the second amplifier.

11. A high frequency oscillator circuit as set forth claim 8 and further including fifth means to stabilize the biasing potential supplied to the first amplifier.

12. A high frequency oscillator circuit as set forth in claim 1 including voltage responsive variable reactance means connected to the tuned circuit to vary the given resonance frequency of the tuned circuit in response to a voltage signal.

13. A high frequency oscillator circuit as set forth in claim 12 in which the variable reactance means include at least one varactor diode.

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Parham

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(43) Date of Patent: Mar. 24, 1998

(54) HIGH FREQUENCY OSCILLATOR CIRCUIT OPERABLE AS FREQUENCY MODULATOR AND DEMODULATOR

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(73) Assignee: PDI Electronics, LLC, 8405 Sartori, Calif.

(61) Appl. No.: 881,817

(62) Filed: Feb. 15, 1997

Related U.S. Application Data

(52) Continuation of Ser. No. 08/504,461, filed 10/1/95, abandoned.

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(54) U.S. Cl.: 332/17.17; 332/17.19; 332/17.19; 332/17.19

(51) Field of Search: 332/17.17, 332/17.19, 332/17.19

332/17.19; 332/17.19; 332/17.19

(56) Prior Art: Siegfried K. Obermaier, et al., "A Frequency Modulated Colpitts Oscillator," U.S. Pat. No. 3,635,734, issued Jan. 10, 1972.

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(5) Oscillator circuits are well known and are employed in numerous applications. There are two primary types of VCO circuits; a relaxation type which employs a resistor-capacitor (RC) constant, and a resonant type which employs a tunable inductor-capacitor (LC) tank circuit. For high frequency applications, resonant tank circuits are preferred due to the frequency accuracy and reduced phase noise they exhibit, their stability and, perhaps most importantly, their high frequency capabilities.

(6) Resonant oscillator circuits are formed from a parallel configuration of an inductance (L) and a capacitance (C). Under ideal conditions, such a parallel L-C arrangement will oscillate in perpetuity. However, due to resistance losses resulting from, *inter alia*, the inductance, the oscillation properties resemble an RLC circuit and result in a damping oscillation. Such an R-L-C circuit is shown in the prior art circuit of FIG. 1, wherein R represents the resistance losses in the circuit caused by the inductor L and capacitor C.

(7) To eliminate the damping effect, the effect of resistance losses R must be cancelled, as for example shown in the circuit of FIG. 1b wherein a transconductance element (denoted as $-R$) is placed in parallel with the inductive losses R to cancel out the resistance. The equivalent schematic representation of FIG. 1b is shown in FIG. 1c wherein capacitor C is replaced by its equivalent, *i.e.* a pair of capacitors having equal value (2C). For tunability, the capacitors are replaced with variable capacitors, as seen in FIG. 1d.

(8) As is known in the art, for VCO frequency stability the product of the L and C values must remain at a high constant value with a relatively large value inductor L used in combination with a small value capacitor. A large L is used for providing a robust oscillator *i.e.* to provide for ease in initiating oscillation of the circuit. It should, therefore, be recognized that if components having undesirably large parasitic capacitance values are used, then for a given LC value a lower value inductor will be required to compensate for the increased capacitance. A problem arises in VCO CMOS design because existing techniques for generating a transconductance element $-R$ to compensate for the LC resistance loss results in relatively high parasitic capacitance. For example, and as shown in FIG. 2a, a CMOS N-channel transistor pair is employed to produce a transconductance effect. The circuit equivalent of FIG.



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FIGS. 1b and 1c are schematic representations of a practical tank circuit with a "negative resistance" (-R) element;

FIG. 1d is a schematic representation of the tank circuit of FIG. 1c with varactors substituted for capacitors;

FIGS. 2a and 2b are alternative schematic representations of a CMOS transistor pair for producing a transconductance value for use as a negative resistance with an LC tank circuit;

FIG. 3 is an LC tank circuit incorporating two CMOS transistor pairs configured as shown in FIGS. 2a and 2b;

FIGS. 4a and 4b are alternative schematic representations of a CMOS transistor pair having a tunable voltage applied to back gate terminals of the transistor pair;

FIG. 5 is a schematic depiction of a tunable LC tank circuit constructed in accordance with the present invention;

FIGS. 6a and 6b are schematic illustrations of LC tank circuits constructed in accordance with an alternate embodiment of the invention;

FIG. 7a is a schematic representation of a practical Colpitts oscillator; and

FIG. 7b is a schematic representation of a Colpitts oscillator in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION:

(1) DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

(2) FIG. 4a depicts a preferred CMOS transistor circuit 30 constructed in accordance with the present invention. Circuit 30 includes a pair of CMOS transistors 32, each having source, drain, gate and back gate terminals. The transistors are arranged so that the gate terminal of one is connected to the drain terminal of the other, and vice versa. The source terminals are

transistor will generate less transconductance than a transistor pair.

(8) As should be readily apparent from the foregoing, the present invention provides for the use of a back-gate driven transistor for simultaneously generating transconductance and variable capacitance. Such a simultaneous function has many practical uses other than in a VCO circuit. For example, a Colpitts oscillator shown in FIG. 7b can be constructed as a substitute for the prior art Colpitts oscillator depicted in FIG. 7a. The Colpitts oscillator of FIG. 7a, consisting of a transistor Q, a capacitor C, an inductor L and a variable capacitance or varactor C' can be designed as the circuit in FIG. 7b wherein the variable capacitance function of the varactor C' is performed by a variable voltage V applied to the back gate terminal of transistor Q in FIG. 7b. Of course, the transistor Q will generate a transconductance value to offset a resistance inherent in the inductor L and capacitor C.

(9) While there have thus been shown and described and pointed out fundamental novel features of the invention as applied to preferred embodiments thereof, it will be understood that various omissions and substitutions and changes in the form and details of the devices illustrated, and in their operation, may be made by those skilled in the art without departing from the spirit of the invention. For example, it is expressly intended that all combinations of those elements which perform substantially the same function in substantially the same way to achieve the same results are within the scope of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the claims appended hereto.

CLAIMS:

I claim:

1. A voltage controlled oscillator CMOS circuit for high frequency operation, comprising:

an inductor having an inherent resistance value;

a first pair of CMOS transistors connected across said inductor, each



Details



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(7) The disadvantage of using local oscillators with doublers or triplers to multiply the frequency is that spurious signals are always present in the output. These spurious signals must be filtered out to avoid degrading receiver performance or interference with other radio services. In addition, running multiple frequency sources wastes power.

(8) The disadvantage of pin diodes is that pin diodes require significant DC current to obtain a low "on" impedance, and when the pin diodes are "off" they can create high levels of harmonically related spurious signals. Moreover, tank circuits associated with the pin diodes reduce circuit Q, which reduces efficiency, and causes higher phase noise in the output circuit.

(9) The disadvantage of using extremely wide band oscillators is that wideband oscillators are necessarily very sensitive to tuning control. This sensitivity makes the oscillator more susceptible to noise on the tuning control line. Correspondingly, more sensitive tuning requires tighter coupling to the tuning (voltage variable reactance) element of the oscillator which causes higher losses in the associated tank circuit.

(10) There is a need for a voltage controlled oscillator that: can generate different frequencies, operates on only one frequency at a time to save power, does not require completely separate oscillator circuits to obtain different frequencies, does not require combiners or pin diodes, has narrow band operation within either of two widely spaced frequency bands, is not sensitive to noise on a tuning control, exhibits a good frequency stability, minimizes spurious frequency signals, has low losses and current drain, and requires simpler, and therefore less costly, circuitry.

DRAWING DESCRIPTION:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a first embodiment of a single output, dual frequency voltage controlled oscillator, in accordance with the present invention;

FIG. 2 is a schematic diagram of a second embodiment of a dual output, dual

(15) FIG. 3 shows a third embodiment of the present invention being a cascode dual switched Colpitts oscillator with two switched buffered outputs (RF output 1 and RF output 2) and one output (RF out). The reference numbers and labels used for FIG. 3 are commensurate with the numbers and labels of FIG. 2 which are hereby incorporated by reference. In the third embodiment RF out 36 is continuously on and is used as a feedback signal for a locked loop signal, such as a phase locked loop, a frequency locked loop, or a delay locked loop. In addition, Q1 and Q2 are equivalent to Q1' and Q2' respectively, R3 is equivalent to R3' and R1 is equivalent to R1'. The circuit of FIG. 3 works substantially the same as that of FIG. 2. The difference of note is that bypass capacitors C bypass (typically 50 pf to 100 pf) coupled the bases of Q1' and Q2' to ground. Also, transistors Q2 and Q2' are biased at a predetermined point and the associated transistor pairs Q1 and Q1' are biased such that when V.sub.control is high, Q1 and Q1' are on and Q2 and Q2' are off. When V.sub.control is low, Q1 and Q1' are off and Q2 and Q2' are on. The use of the buffering transistors Q1' and Q2' advantageously reduces loading of the oscillator.

(16) FIG. 4 shows a fourth embodiment of the present invention being a common base Colpitts (Seiler) oscillator design. The reference numbers and labels used for FIG. 4 are commensurate with the numbers and labels of FIG. 3 which are hereby incorporated by reference. In this embodiment the resonators 26, 28 are coupled in a respective collector circuit of each transistor Q1 and Q2. The operation of this embodiment is essentially the same as that of FIG. 3 with the addition of appropriate RF chokes and bypass capacitors as shown. This circuit may be operated as a single output design (dual bands from RF out 36), or optionally as a dual output design (single band operating from either of RF output 1 (38) or RF output 2 (40)) with an RF feedback signal provided by RF out 36 for use as a locked loop signal, such as a phase locked loop, a frequency locked loop, or a delay locked loop.

(17) FIG. 5 shows a fifth embodiment of the present invention being a Butler oscillator design. The reference numbers and labels used for FIG. 5 are commensurate with the numbers and labels of FIG. 4 which are hereby incorporated by reference. In this embodiment the resonators 26, 28 are coupled in a respective emitter circuit of each transistor Q1 and Q2. The operation of this embodiment is essentially the same as that of FIG. 4. This circuit may be operated as a single output design (dual bands from RF out 36).

circuit, a crystal for controlling the oscillator frequency, and an output signal terminal. One of the well-known crystal-controlled oscillators is the Colpitts oscillator using a series resonant crystal to ground a transistor amplifier base. Another is the Colpitts oscillator with the crystal in a series resonant mode between the emitter of the transistor amplifier and the junction of two capacitors coupling the collector to a ground terminal.

(9) Another of the most commonly used crystal oscillator circuits is the Pierce oscillator. This is basically a common-source Colpitts circuit with the crystal forming a resonant circuit with a first capacitor that couples the source and the drain and a second capacitor that couples the gate and the source with the source being at ground potential.

(10) Still another well-known circuit is the Miller oscillator in which both the crystal and an output tank circuit look like inductive reactances at the oscillation frequency.

(11) Yet another well-known oscillator is the Clapp oscillator which is actually a Pierce oscillator with the base rather than the emitter at AC ground. The Clapp oscillator can be thought of as a grounded-base amplifier stage loaded with a tank circuit. The tank circuit has a capacitive tap from which energy is fed back to the emitter.

(12) In all of these circuits, it is well known that the amplifiers have some degree of nonlinearity. The existence of nonlinearity implies distortion. In other words, the output will contain not only the desired frequency but also some of its harmonics. In some applications, the presence of harmonics may be unimportant but in others there is a requirement of a sine wave of the highest possible purity. One fairly obvious way of removing unwanted harmonics is to pass the output of the oscillator through a suitable tuned band-pass or low-pass filter. This works quite well if the frequency of the oscillator is fixed, but it is very inconvenient if a variable frequency is required as the filters then have to be tuned in step with the change in desired frequency. Such filters are normally designed with capacitors and inductors to form either low-pass or band-pass filters coupling the oscillator output to the desired load. Of course, there are other types of filter circuits that can also be used. Such filters are expensive and require the use of additional space where space is at a premium.

(19) It is still another object of the present invention to improve crystal-controlled oscillator circuits such as the Colpitts oscillator circuit, the Pierce oscillator circuit, the Miller oscillator circuit, the Clapp oscillator circuit, and any crystal-controlled feedback oscillator circuit.

DRAWING DESCRIPTION:

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the present invention will be more fully disclosed when taken in conjunction with the following DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT in which like numerals represent like elements and in which:

FIG. 1 is a circuit diagram of a prior art Colpitts oscillator using the crystal in the series-resonance mode;

FIG. 2 illustrates the same oscillator with the crystal being replaced by the two-port SAW resonator filter to form the novel oscillator of the present invention;

FIG. 3 is a circuit diagram of a prior art Colpitts oscillator using a series-resonant crystal to ground the transistor base;

FIG. 4 is a circuit diagram of the Colpitts oscillator of FIG. 3 with the crystal therein being replaced by the two-port surface acoustic wave resonator filter of the present invention to provide a Colpitts oscillator circuit having an output signal with very low harmonic content;

FIG. 5 is a circuit diagram of a prior art Pierce crystal oscillator;

FIG. 6 is the circuit diagram of the Pierce crystal oscillator of FIG. 5 with the crystal therein replaced by the two-port surface acoustic wave resonator filter of the present invention to provide an oscillator output signal having very low harmonic content;

FIG. 7 is a circuit diagram of a prior art Clapp oscillator circuit having a crystal therein.

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(3) In the circuit of FIG. 1, the Colpitts oscillator is a well-known oscillator circuit that includes the transistor 10 as an amplifier or gain element, the crystal 12 serving as the signal feedback circuit and also establishing the oscillator frequency, and a load resistor 14. The output signal can be developed at an output terminal 16 across the load resistance 14. The piezoelectric crystal 12 has an equivalent electrical circuit as shown in FIG. 11(a). It has an inductance, $L_{sub.x}$, a resistance, $R_{sub.x}$, and a capacitance, $C_{sub.s}$, all in series and the series circuit is paralleled by a capacitance, $C_{sub.p}$, that represents the capacitance introduced by the crystal electrodes. FIG. 11(b) illustrates the reactance curves for the crystal circuit of FIG. 11(a) and shows that there is a possibility of both resonant and anti-resonant modes of operation occurring as illustrated by curves 2 and 4, respectively.

(4) FIG. 2 is an improved version of the Colpitts oscillator of FIG. 1 according to the present invention. It will be noticed in FIG. 2 that the crystal 12 of FIG. 1 has been replaced with an element 18 formed of a piezoelectric material having a first electrical signal port 20 and a second electrical signal port 22. The terminals of the first signal port 20 are connected to the terminals 24 and 26 from which the crystal 12 was removed. The second signal port terminals 22 form the output terminal for providing the oscillator frequency. Because the element 18 is a two-port SAW resonator filter, designed at the frequency at which the circuit oscillates, it has relatively low harmonic levels at the output. The first port 20 of the two-port SAW resonator filter 18 has a similar equivalent circuit as shown in FIG. 11(a). In order for the filter 18 to operate most efficiently in the application of the present invention, the impedance characteristic of the equivalent circuit should be a low-loss circuit with the value of $R_{sub.x}$ and $C_{sub.p}$ minimized as much as practicable and the circuit should have a primarily inductive mode of operation as shown by curve 6 on the well-known Smith chart in FIG. 12. Such design characteristics can be obtained by those skilled in the SAW device art.

(5) FIG. 3 is a circuit diagram of a Colpitts oscillator similar to that shown in FIG. 1 except that it uses a series-resonant crystal 12 to ground the transistor base. The crystal 12 grounds the base of transistor 10 at terminal 28 at the crystal center frequency. Thus, the frequency of the oscillator is

a Pierce oscillator with the base rather than the emitter at AC ground. The Clapp oscillator can be thought of as a grounded-base amplifier stage 36 with a tank circuit. The tank has a capacitive tap from which energy is fed back to the emitter. Again, the crystal 12 establishes the frequency of oscillation of the circuit. The output is derived across load resistor R.sub.L through coupling capacitor C.sub.c.

(10) FIG. 8 is a novel circuit diagram of the Clapp crystal oscillator of FIG. 7 that has been modified to form an oscillator of the present invention. Again, it has a two-port SAW resonator filter 18 having input port terminals 20 connected between the collector of transistor 36 and ground in place of the crystal 12. It also has its output port terminals 22 from which the output frequency signals are taken. Again, for reasons previously given, the output frequency of this oscillator has very low harmonic content.

(11) The well-known Miller oscillator circuit of the prior art is illustrated in FIG. 9 in schematic representation. It is similar to a tuned-input, tuned-output circuit in which both the crystal 12 and the output tank circuit 38 look like inductive reactances at the oscillation frequency. Although the output of FET 40, or drain circuit, could consist of just an inductor, a higher effective reactance can be achieved by means of the tuned circuit 38. The principal advantage of this circuit is that one side of the crystal 12 along with one side of any parallel frequency-adjustment capacitor are grounded.

(12) FIG. 10 illustrates a circuit diagram of a Miller oscillator such as that shown in FIG. 9 that has been modified to form an oscillator of the present invention. Again, it has the two-pole SAW resonator filter 18 having its first port input terminals 20 coupled in place of the crystal 12 between the gate of FET 40 and ground. The second port terminals 22 form an output from which the oscillator frequency is taken. Again, the amplifying device 40 may be any kind of gain device such as a transistor or a FET.

(13) Many other crystal oscillator circuits exist and there is a considerable body of literature showing examples of circuits that worked with the design procedure unstated. There are many existing excellent surveys of crystal oscillator types and performance.

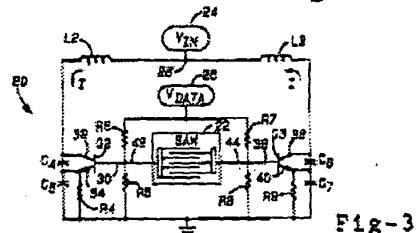
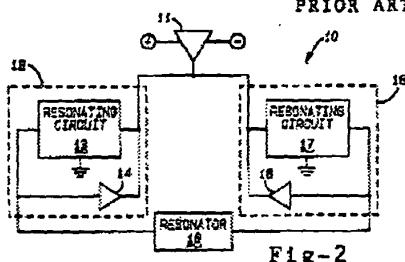
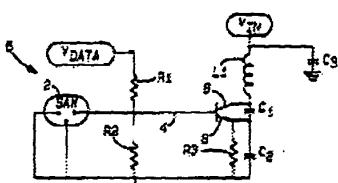
(14) Thus, there has been disclosed a novel oscillator circuit which is a

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(6) Currently, a number of compact remote RF transmitters employ a single oscillator design for providing a local oscillation signal. As illustrated in FIG. 1, a conventional transmitter circuit 5 is shown with a single oscillating circuit commonly referred to as the Colpitts oscillator. Transmitter circuit 5 generates a local oscillation signal which is transmitted from an antenna element L.sub.1. In light of its simplicity, circuit 5 has been the transmitter component of choice in automotive, remote controlled, keyless entry systems.

(7) Referring to FIG. 1 in greater detail, the Colpitts oscillator of circuit 5 comprises a Colpitts configured transistor Q.sub.1 and an input resonant tank circuit. The tank circuit typically comprises a resonator, such as a surface acoustic wave ("SAW") device 2, and a pair of feedback capacitors, C.sub.1 and C.sub.2. Further, the oscillator also includes a number of biasing resistors to facilitate the proper operation of transistor Q.sub.1. Transmitter circuit 5 also comprises an inductor L.sub.1 which acts as an antenna element for radiating the RF output signal.

(8) Structurally, transistor Q.sub.1 comprises a base 4, collector 6 and emitter 8. Base terminal 4 is coupled with surface acoustic wave resonator 2, and collector 6 is coupled with inductor L.sub.1, while emitter 8 is coupled to ground through a resistor R.sub.3. Additionally, feedback capacitor C.sub.2 is coupled between emitter 8 and ground, and as such, is in parallel with resistor R.sub.3. Feedback capacitor C.sub.1 is coupled between collector 6 and emitter 8. Moreover, a third capacitor C.sub.3 is coupled between inductor L.sub.1 and ground for providing a large capacitance to maintain a constant DC voltage.

(9) Circuit 5, and more particularly L.sub.1 and C.sub.3, is coupled to a direct current ("DC") voltage source to receive a DC bias input V.sub.IN, typically 6 V. Transmitter circuit 5 also receives a data input signal V.sub.DATA for encoding the RF carrier signal. As detailed hereinabove, circuit 5 generates a radiating output signal via inductor L.sub.1. In doing so, transistor Q.sub.1, acting as an amplifier, in combination with the resonating tank circuit, generates a resonating signal which is provided to inductor L.sub.1 as an oscillating current signal I. The conduction of current I through inductor L.sub.1 in turn causes the radiating output signal to be transmitted as an electromagnetic field.

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(10) The above described Colpitts oscillator is well suited for the RF signal transmission applications of a remote keyless entry system. However, such an oscillator design provides a limited amount of power output. Further, the alternative of a greater inductance value for radiating inductor L_{sub.1} may not feasibly achieve a corresponding increase in power due to the inherent limitations of such components. Similar attempts to enhance output power through the optimization of component values has proved futile in view of the matching losses created thereby. Moreover, rail-to-rail voltage swings in transistor Q_{sub.1} tend to confine the amount of current flow through the circuit which, in turn, diminishes the available power output realized by a given transmitter circuit.

(11) As a result of the limited power available from compact remote transmitters using Colpitts oscillators, another problem has arisen with their application in compact remote transmitters. Typically, compact remote transmitters are hand grasped and directed generally toward a receiver of the system. By so doing, a parasitic impedance is created by the user's hand. This additional impedance reduces the amount of transmitted energy towards the receiver. This becomes an issue of particular significance in view of the limited power available from a traditional Colpitts oscillator.

(12) In view of these problems, a need remains for an oscillator circuit having an increased power output. A demand further exists for a method of efficiently generating and transmitting an RF signal having increased power output. Moreover, industry requires an oscillator circuit which is substantially immune to parasitic impedances. cl SUMMARY OF THE INVENTION

(13) The primary advantage of the present invention is to overcome the limitations of the prior art.

(14) Another advantage of the present invention is to provide for a balanced oscillator and transmitter having enhanced power output characteristics.

(15) A further advantage of the present invention is to provide for a balanced oscillator and transmitter substantially immune to parasitic impedances.

(16) Still another advantage of the present invention is to provide for a

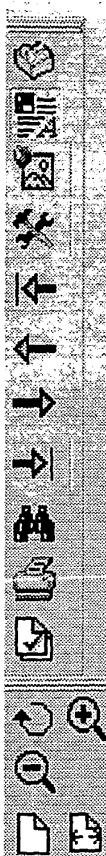
oscillator and transmitter system of FIG. 2. Balanced oscillator and transmitter circuit 20 comprises a first and second pseudo Colpitts oscillator. Both pseudo Colpitts oscillators are balanced with respect to one another and share a common tank circuit and oscillating current signal I for power output efficiency. Circuit 20 described herein is particularly applicable with automotive remote keyless entry systems. Other applications, however, are clearly conceivable to one of ordinary skill in the art.

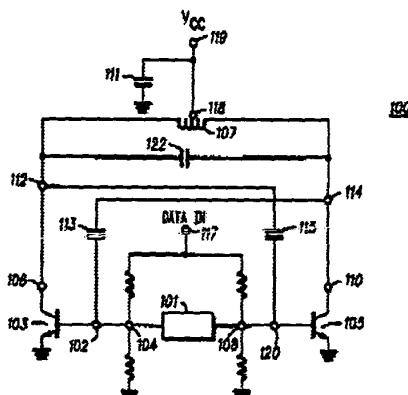
(9) According to a more detailed description, circuit 20 comprises a balanced oscillator configuration which includes two pseudo Colpitts oscillator circuits for producing a local oscillation signal. The oscillator circuitry includes a first transistor Q.sub.2 and a second transistor Q.sub.3 each coupled with a resonator device 22 therebetween. Resonator device 22 acts as a series resonant input tank for generating and stabilizing the oscillating current signal I. By so doing, a resonance RF carrier frequency is achieved.

(10) First and second transistors, Q.sub.2 and Q.sub.3, each preferably comprise a bipolar junction transistor ("BJT"). Alternatives, however, such as a heterojunction bipolar transistor ("HBT"), should be apparent to one of ordinary skill in the art. According to a further embodiment, transistors Q.sub.2 and Q.sub.3 are each MMBTH10 type bipolar transistors.

(11) Transistors Q.sub.2 and Q.sub.3 each operate as an amplification stage to provide a unity loop gain for steady state operations. First transistor Q.sub.2 comprises a base, a collector, and emitter 30, 32 and 34, respectively. Likewise, second transistor Q.sub.3 comprises a base, a collector, and emitter 36, 38 and 40, respectively. Transistors Q.sub.2 and Q.sub.3 are each configured as a pseudo Colpitts oscillator having a tuned LC circuitry and positive feedback. It should be understood by one of ordinary skill in the art that various other transistor oscillator configurations may be substituted into the above arrangement to achieve the same functional purpose.

(12) Resonator device 22 is coupled between the base terminals 30 and 36 of transistors Q_{sub.2} and Q_{sub.3} via resonator output lines 42 and 44, respectively. Resonator 22 is shown having an array of metallic fingers formed on a piezoelectric substrate. Resonator 22 advantageously operates to stabilize oscillations of the carrier signal. Resonator device 22 preferably comprises a series resonant input tank circuit, surface acoustic wave ("SAW")





An oscillator-transmitter (100) includes an input tank circuit (101) coupled between a first amplifier (103) and a second amplifier (105) configured in an oscillator arrangement. An output tank circuit (107, 109, 111), for radiating radio-frequency energy, is coupled between outputs (106, 110) of the first and second amplifiers (103, 105). The output tank circuit (107, 109, 111) radiates energy provided by both the first and second amplifiers (103, 105).

24 Claims, 2 Drawing figures

Exemplary Claim Number: 1

Number of Drawing Sheets: 1

BRIEF SUMMARY:

(1) **FIELD OF THE INVENTION**

(2) This invention is generally directed to the field of radio frequency oscillator-transmitters, and more particularly to a specific architecture for an oscillator-transmitter.

(3) **BACKGROUND OF THE INVENTION**

(4) Radio frequency (RF) oscillator-transmitters are constructed using different architectures. In battery operated designs, such as those found in remote-keyless-entry (RKE) oscillator-transmitters, an ever-present design challenge is to output maximum power with minimum power drain on the battery.

(5) One architecture, commonly used in RKE oscillator-transmitters, is based on a Colpitts oscillator configuration. One transistor amplifier Colpitts oscillator designs do not output enough power for a given battery operating voltage for most applications. Two transistor amplifier Colpitts oscillator designs use two separate oscillator circuits, each with its own output tank circuit configured in a common-base configuration. Although the two transistor amplifier designs offer more output power for a given battery operating voltage than the single transistor amplifier designs, this approach is costly and more difficult to manufacture because two separate output tank circuits must be

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reliable in field use. Additionally, two transistor amplifier common-base configured Colpitts oscillator designs unnecessarily load reactive elements in the oscillator circuit causing a reduced Q which results in a less stable oscillator that generates a less pure sine wave. Corrupted purity is a major performance disadvantage in a radio system because transmitted output power is regulated by authorities to include a measure of purity. Thus, if the transmitted energy is not of a pure sine wave form, then the oscillator output power must be trimmed back so as not to interfere with other radio frequency systems.

(6) What is needed is an oscillator-transmitter design that is power efficient, reliable, outputs a relatively pure sine wave, and is also easy to manufacture.

DRAWING DESCRIPTION:

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic drawing showing a preferred architecture for an oscillator-transmitter in accordance with a preferred embodiment of the invention; and

FIG. 2 is a schematic drawing showing another architecture for an oscillator-transmitter in accordance with an alternative embodiment of the invention.

DETAILED DESCRIPTION:

(1) DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

(2) An oscillator-transmitter includes an input tank circuit coupled between a first amplifier and a second amplifier configured in an oscillator arrangement. An output tank circuit, for radiating radio-frequency energy, is coupled between outputs of the first and second amplifiers. The output tank radiates energy provided by both the first and second amplifiers. Preferably the oscillator-transmitter is operated at 315 MHz. This arrangement is power efficient and has fewer components than prior art two amplifier oscillator circuits that used separate tank circuits coupled to the two amplifiers. Furthermore, with fewer components this design is more reliable. To better

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oscillator-transmitter in accordance with a preferred embodiment of the invention. An oscillator-transmitter circuit 100 includes a input tank circuit that uses a two terminal surface acoustic wave (SAW) device 101 to determine an initial operating frequency.

(4) A first transistor amplifier 103 has an input 102 coupled to a first terminal 104 of the surface acoustic wave device 101. The first transistor amplifier 103 also has an output terminal 106. A second transistor amplifier 105 has an input 120 coupled to a second terminal 108 of the surface acoustic wave device 101. The second transistor amplifier 105 also has an output terminal 110.

(5) An output tank circuit for radiating energy has a center-tap inductor 107 with a first terminal 112, a second terminal 114, and a center-tap terminal 118. A tank capacitor 122 is coupled between the first terminal 112 and the second terminal 114 of the inductor 107. The center-tap terminal 118 of the inductor 107 is connected to a direct current type power supply 119. The output terminal 106 of the first transistor amplifier 103 is coupled to the first terminal 112, and, the output terminal 110 of the second transistor amplifier 105 is coupled to the second terminal 114.

(6) To complete the oscillator-transmitter circuit 100, symmetrical feedback paths, to the common-emitter configured first and second transistor amplifiers 103 and 105, are formed using a first feedback capacitor 113 and a second feedback capacitor 115. Also a DATA IN (data input) terminal 117 provides an input to which modulating data is fed into the oscillator-transmitter circuit 100 to modulate the oscillator-transmitter circuit 100. Preferably, the DATA IN terminal 117 is used to amplitude modulate the energy output of the oscillator-transmitter circuit 100.

(7) In an alternative embodiment illustrated in FIG. 2, an alternative oscillator-transmitter circuit 200 has an output tank circuit with the center-tap inductor 107 coupled between a first capacitor 109 at the first terminal 112. The inductor 107 is also coupled between a second capacitor 211 at the second terminal 114. The output terminal 106 of the first transistor amplifier 103 is coupled to the first terminal 112 between the first capacitor 209 and the inductor 107. And, the output terminal 110 of the second transistor amplifier 105 is coupled to the second terminal 114 between the second capacitor 211 and the inductor 107. Both capacitors 209 and 211 are

second capacitor 211 and the inductor 107. Both capacitors 209 and 211 are directly connected to an alternating current (AC) ground terminal 222.

(8) One advantage of the oscillator-transmitter circuits 100 and 200 is the significant improvement in output power capability over conventional single transistor Colpitts oscillator configurations. The reason for this is that the signal present at terminals 106 and 110 have a voltage of approximately the same amplitude but are out of phase by 180 degrees when measured relative to circuit ground 222. Since these signals are active across the output tank circuit (107 and 122), and are out of phase by 180 degrees the voltage across the output tank circuit (107 and 122) is effectively doubled to six volts in a three volt battery powered circuit and therefore the output power emitted through the output tank circuit (107 and 122) is much higher than in the prior art single transistor Colpitts oscillator configuration.

(9) Another advantage of the oscillator-transmitter circuits 100 and 200 compared to conventional two transistor common-base configured Colpitts oscillators relates to transmitted power purity and oscillator stability. Since the transistor amplifiers in the present oscillator-transmitter circuits 100 and 200 are configured in a common-emitter configuration, loading of the output tank circuit (107 and 122) is significantly less than in the common-base configuration. This reduced loading results in a higher Q for the output tank circuits and also in generation of a purer sine wave. Additionally, the collector-base capacitive feedback used in the oscillator-transmitter circuits 100 and 200 is better than the arrangement necessary in a common-base design because it also presents a lesser load to the output tank circuit (107 and 122), resulting in a more stable and pure emission of power.

(10) The oscillator-transmitter circuits 100 and 200 are also more reliable and easier to manufacture than a two transistor amplifier Colpitts oscillator designs that use two separate oscillator circuits each with its own output tank circuit, because there are fewer components to assemble and fail.

CLAIMS:

What is claimed is:

